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The Spectrum of the Lighter Constituents of the Air.

By HERBERT EDMESTON WATSON, B.Sc. (Lond.).

(Communicated by Sir William Ramsay, F.R.S. Received June 23,—Read June 25, 1908.)

In 1900, Professors Liveing and Dewar published a paper on “The Lighter Constituents of Air,”* and gave a table of wave-lengths for nearly 300 lines. Some of these were shown to be produced by hydrogen, helium, and neon, but the greater number were of unknown origin.

A few years later the spectrum of pure neon was published by Baly,† and it was shown that many of Liveing and Dewar’s lines were due to that gas, but at the same time 162 lines remained which, in the opinion of that observer, did not belong to neon.

With the view of throwing some light on the matter, and ascertaining more definitely whether there was a constituent of the air of lower atomic weight than helium, Coates‡ fractionated a large quantity of air, but could find no constituents other than hydrogen, helium, and neon on examining the lightest fractions with a small prism spectroscope.

In order, however, to make quite sure of this point, Sir William Ramsay requested me to photograph the spectrum with the Rowland grating at University College, and the results of this work form the material of the present communication. The main object of the research, namely, definite proof of the existence of a new gas, has been unsuccessful, as was to be expected from the preliminary work, but incidentally it has been shown that the neon spectrum is considerably more complicated than was formerly supposed, and a number of new lines have been measured.

Experimental.

The method of fractionation of the gas has already been fully described by Coates,§ but it may be as well briefly to recapitulate it. About 73,000 litres of air were continually circulated through the liquefying apparatus at University College until greatly reduced in volume by the condensation of the least volatile portions. The residue was then condensed in portions of about 80 litres in a glass bulb immersed in liquid air boiling

* ‘Roy. Soc. Proc.’ vol. 67, pp. 467—474, 1900.

† ‘Phil. Trans.’ A, vol. 202, pp. 183—242, 1903.

‡ ‘Roy. Soc. Proc.’ A, vol. 78, pp. 479—482, 1906.

§ *Loc. cit.*

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under reduced pressure. Light fractions were boiled off, and the process repeated several times until the volume was reduced to 4700 c.c. The portion of this gas which was not absorbed by charcoal at -190° C. was separated into several fractions. Fraction 1 was pumped off charcoal at -205° C., and fraction 2 at -190° C. These were the two fractions examined spectroscopically. It is worthy of note that analysis showed neither of them to contain any appreciable quantity of hydrogen, this gas only boiling off at a higher temperature.

The form of vacuum tube used was one in which the capillary portion was viewed end on through a quartz plate cemented on with sealing wax. The electrodes were situated in side tubes, so that the spectrum of the gas surrounding them was not photographed as in the experiments of Liveing and Dewar. They were made of stout aluminium wire, and mounted as described by Baly.* Baly's methods of filling the tubes and adjusting the pressure in them were also adopted, except with regard to removing the last traces of hydrogen from the electrodes, this gas being present in small quantities in the gas to be examined.

The Rowland grating used has a focal length of 10 feet, and is ruled with 14,438 lines to the inch. When finally adjusted, it was found that the centres of lines of different orders upon the same plate were not in the same horizontal line, and consequently it was easy to distinguish lines of different orders. This displacement was slight, and does not appear to have affected the relation between wave-lengths measured in different orders.

The spectra obtained were remarkably free from ghosts, and, in fact, when first set up, the grating was supposed to be perfect in this respect. I have found, however, that on prolonged exposure all the very intense lines are accompanied by four ghosts, the outer pair being some distance from the true line. They were recognised by the property of symmetry about the principal line, and were in several cases used to determine the true position of the latter. If one ghost were masked by another line, the position of the corresponding ghost was calculated by means of the fact that the distance from the principal line is proportional to the wave-length. It is hoped that by this means all spurious lines have been removed from the table of wave-lengths.

The whole spectrum was photographed in the first order, but lines of wave-length less than 4100 were measured in the second order as well. The plates used were Wratten and Wainwright's "Panchromatic," the sensitiveness of which is practically equal for all portions of the spectrum below 7000. For the red region the "spectrum" plates of the same firm

* *Loc. cit.*

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were used, these being sensitive to at least 7900. I am greatly indebted to Dr. Mees for personally making them for me.

It was found preferable to make exposures during the night, as there was less vibration and the temperature remained more constant. The second condition was very important, since it was found possible to obtain first-class plates only when the temperature variation was less than 1° ; but the grating being situated in the basement, the variation during one night seldom exceeded 3° , and was usually much less. All the plates were taken between the temperatures 11° and 18° C.

Exposures of about 16 hours were given, this comparatively long time being necessary to show many faint lines which exist in the spectrum. The very strong lines in the orange region were photographed with tubes which had partially run down, in order to avoid over-exposure. In all cases a weak current from an induction coil without a Leyden jar was used, so as to prolong the life of the tubes as much as possible. After each exposure an iron spectrum was photographed below that of the gas, the slit being screened so that the points of the longer lines in the two spectra just met. As the relative positions of the principal neon lines and standard iron lines had been already determined by Baly, it was considered unnecessary to repeat this work. The wave-lengths of iron lines given by Kayser and Runge* were, however, used to eliminate errors, according to the method described by Baly,† with the exception that the correction applied to the wave-length of a gas line differed from the value deduced from the correction curve by a small number which was constant for any one plate, and of such a magnitude as to make the corrected wave-lengths agree as nearly as possible with Baly's. This procedure is necessary, because the gas and iron spectra were photographed through different portions of the slit and consequently were apt to suffer a slight relative displacement.

The error in the wave-lengths given is difficult to estimate. All the plates were measured at least twice, and the readings in nearly every case agreed within 0.001 cm., a distance corresponding to 0.05 Ångström unit. Usually the agreement was much better. The wave-lengths, as determined from different plates, agreed in general within 0.04 A.U., but those of the very strong and very weak lines sometimes differed by as much as 0.1 A.U., and in such cases they were remeasured. Any values which differed much from those given by Baly were also carefully revised. In the red part of the spectrum, and the region from 5000 to 4000, a number of plates were taken, and it is hoped that the error in the wave-lengths is not greater than

* 'Brit. Ass. Reports,' 1891, p. 161.

† 'Spectroscopy,' p. 221.

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0.03 A.U. This also applies to lines of shorter wave-length than 4000, as they were measured in two orders. Baly has measured nearly all the lines in the remainder of the spectrum, and his results are probably the more accurate since they were deduced from photographs in the second order. The hydrogen, helium, and mercury lines which were found in the spectrum afforded a means of checking the absolute wave-lengths, and the agreement was found to be good throughout.

The Constituents of the Gas.

As before mentioned, two fractions of gas were examined, one pumped off charcoal at a temperature of -205°C . and the other at -190°C . After a complete series of photographs of each fraction had been taken the gases were sparked for a considerable time with oxygen, and the latter removed by means of phosphorus. This procedure had no effect on the spectrum beyond removing the hydrogen lines, and moreover the two fractions appear to be identical as regards their constituents, the only difference being in the relative intensities of some of the lines.

The spectrum consisted entirely of bright lines, and no trace of nitrogen or carbon compounds could be detected. Three of the brightest mercury lines were obtained from freshly filled tubes, but were only just visible. The small quantity of hydrogen present in the gas before sparking was a source of considerable difficulty since there appears to be at present no reliable table of the wave-lengths of the secondary hydrogen spectrum. Ames* has published a list of lines obtained from a vacuum tube of hydrogen, and about half these appeared on my plates. No trace of the weaker lines was to be seen, and hence it appeared unlikely that any other hydrogen lines would be present. There were, however, several faint lines on my plates which appeared only occasionally, and these were all found in a list given by Frost† of lines which appeared in a helium tube after running for some time. The region of the spectrum embraced is only from 4723—4358, but from comparison with Hasselberg's original secondary hydrogen spectrum‡ it is concluded that these lines are due to hydrogen. The number of them is 90, of which only nine are given by Ames. It appears, therefore, that there is a spectrum of hydrogen which is seen only under exceptional circumstances, one of the most favourable of which is the presence of a monatomic gas. A further investigation of this point is in progress. Owing to the limited range of Frost's values it is possible that a

* 'Phil. Mag.,' vol. 30, p. 33, 1890.

† 'Astrophys. Journ.,' vol. 16, p. 104, 1902.

‡ Watts, 'Index of Spectra,' p. 50.

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few hydrogen lines have not been removed from the table of wave-lengths, but their number is not likely to be great because the relative intensities of nearly all the lines given were constant on different plates taken with different tubes.

All the helium lines given by Runge and Paschen,* except the very weakest, were seen and measured, but the helium spectrum was not nearly as strong as that of the neon. In some cases the former was very faint indeed owing to the selective absorption of the helium by the electrodes, and on one plate no trace of the line 5875·8 was to be seen. The lines at 6678 and 3447, however, were very bright on the same plate, and it must be concluded that these are two neon lines almost coincident with the helium lines. The line at 3447 is, moreover, given by Baly as a strong line, though in his tubes the helium was always allowed to run out before a photograph was taken. There appears to be a similar pair at 4713, though I was unable to obtain a plate on which the neon line alone was present. The wave-lengths of the lines concerned are :—

He ...	...	6678·37	4713·25	3447·73
Ne ...	...	6678·50	4713·51	3447·83

and no reason can be at present assigned to their close proximity.

Argon was present in minute traces, even after the exhaustive fractionation the gas had undergone; it is not surprising, therefore, to find that Baly's gas also contained argon, and several lines given by him are due to this substance. All that have been found are given in the tables, and have not been eliminated as have the lines due to gases previously mentioned.

The question which now arises is: What is the origin of the remaining lines? Their number is 321, of which only 115 are given by Baly, and 132 by Liveing and Dewar, and it might well be supposed that some of them are due to elements as yet unknown. Accordingly their wave-lengths were carefully compared with those of the chief nebular lines as measured by Wright,† and the coronal lines given by Lockyer.‡ There was not the slightest indication of the existence of any of these lines in my spectrum. Marshall Watts, in a list of auroral lines,§ assigns some to neon, but the wave-lengths given are not sufficiently accurate to enable definite conclusions to be drawn. In addition, Dyson's|| list of 1200 lines in the chromosphere

* 'Astrophys. Journ.,' vol. 3, p. 4, 1896.

† 'Astrophys. Journ.,' vol. 16, p. 53, 1902.

‡ 'Roy. Soc. Proc.,' vol. 66, p. 191, 1900.

§ 'Monthly Weather Review,' vol. 35, p. 408, 1907.

|| 'Phil. Trans.,' A, vol. 206, pp. 403—452, 1906.

of the sun was examined. A certain number of approximate coincidences were observed, and are noted in the table of wave-lengths, but it is highly probable that they are merely accidental, for the lines in question are remarkable neither for their intensity nor their character.

This being so, another explanation was looked for. It will be observed that all the lines not given by Baly are of comparatively low intensity, and occur largely in the ultra-violet, and hence it is quite probable that they are really neon lines which were not previously obtained owing to insufficient exposure. Baly's photographs were all in the second order, which for the particular grating used is not nearly as bright as the first, and, moreover, his vacuum tube had a thin glass end which would naturally obliterate much of the ultra-violet light. To confirm this supposition a different sample of neon and helium containing considerably more helium than the former one was photographed. The lines ascribed to neon were all seen, and were identical in intensity with those formerly obtained, so that it appears very unlikely that any gases other than helium and neon were present in either sample. There is, of course, the possibility that a gas very similar to neon in physical properties exists, but the periodic table renders this unlikely, and it is to be expected that a gas with lower atomic weight than helium would resemble this gas substance rather than neon, with the result that its spectrum would be relatively stronger in the second sample examined. It may consequently be stated fairly conclusively that the spectrum of a new gas has not been photographed, but this is by no means synonymous with saying that such a gas does not exist. There are at least three reasons for this. Firstly, it was remarked by Coates that the fractions of air distilled from charcoal at -190° C. contained hardly any hydrogen, this gas boiling off only at a higher temperature. Consequently, it is possible that another gas might behave similarly, and if this were the case its spectrum would probably be masked by that of the nitrogen in the later fractions. Secondly, as already mentioned, the helium in the gas was absorbed by the electrodes more readily than the neon, and a third gas might be absorbed almost at once before its spectrum could be photographed. Thirdly, it has been observed by Cameron and Ramsay* that helium is absorbed by glass and silica even in the cold, and it is therefore just possible that a monatomic gas of very low atomic weight might pass through these substances with ease, and if this be so it seems unlikely that a lighter constituent of air will ever be isolated.

It still remains to make a few remarks about the tables of Baly, and Liveing and Dewar. Baly makes no mention of the strong line 6334,

* 'Chem. Soc. Trans.,' vol. 91, p. 1279, 1907.

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although it is assigned to neon by Liveing and Dewar. I have been unable to find the reference for this, but it seems likely that the omission is due to a clerical error. The same author also gives several lines not in my list. Some of these I have identified as argon lines, some as ghosts, and a few as belonging to a different order, but the most careful search has failed to reveal any trace of the rest.

The origin of many of Liveing and Dewar's lines is by no means clear. Since these observers liquefied only about 200 litres of air, less than a three-hundredth part of the amount treated by Coates, it does not seem at all likely that they can have obtained any gas which was unnoticed by the latter. Their gas, however, contained considerable quantities of hydrogen, and though it is stated that the hydrogen lines were not usually visible when photographs were taken, owing to the passage of this gas to the positive pole, yet it may have happened that there was hydrogen round the negative pole as well, but that this yielded a hitherto unrecognised spectrum. If this be not admissible, it must be supposed that the negative pole has some peculiar influence upon the gas in its immediate neighbourhood which complicates the spectrum considerably.

The following tables show the wave-lengths obtained, those of Baly, and Liveing and Dewar being added for the sake of comparison. The intensities are given in the usual way, with 10 as maximum, although this method of representing them is wholly inadequate, and in fact misleading. Many lines of apparently the same intensity differ greatly in reality, and the strongest lines are many hundred times as intense as the weakest. 0 represents a line which can just be measured with a low-power microscope. A few weaker lines could be seen with a small lens, but could not be measured, and are omitted. Anything noticeable about a particular line is placed in the column headed "Remarks."

In conclusion, I should like to tender my warmest thanks to Sir William Ramsay for the great interest he has taken in this work, for personally sparking down and repurifying the gases, and for frequently undertaking the laborious process of remaking and refilling the vacuum tubes. Also to Mr. Baly for advice with regard to the use of the grating, and to Mr. Coates for some help in the earlier part of the work.

Note added July 28.—Since going to press, the hydrogen spectrum has been completely photographed. Only one hydrogen line was found in the table of wave-lengths, and this has now been removed.

Wave-length.	Intensity.	Baly.	Intensity.	Livinge and Dewar.	Remarks.
7245·47	2	—	—	7247	The wave-lengths of these red lines carefully standardised from the helium lines 7065·48, 6678·37, 3705·15, 3613·79, and 3354·67
7174·25	2	—	—	7174	
7059·50	2	—	—	7058 vw	
7032·65	3	—	—	7034	
7024·38	2	—	—	—	
6929·78	6	—	—	6931	Not Helium 6678·37
6759·72	1	—	—	—	
6738·17	2	—	—	—	
6717·22	7	·20	1	6716	
6678·50	9	—	—	6678·4	
6667·05	3	—	—	—	Very weak in first fraction
6652·20	4	—	—	—	
6640·23	1	—	—	—	
6603·10	3	—	—	—	
6599·18	9	·16	4	6601	
6533·08	6	·10	4	6535	L. and D. remark that this is a neon line
6506·69	9	·72	6	6508	
6444·88	4	·90	1	6446 vw	
6421·89	2	—	—	—	
6409·93	3	·90	1	—	
6202·43	10	·40	10	6404	6304
6401·24	6	·26	1	—	
6383·14	9	·15	8	6382	
6365·23	2	—	—	—	
6352·08	4	·04	1	—	
6334·65	9	—	—	6334	6217
6331·11	5	·13	1	—	
6328·39	6	·38	6	—	
6313·89	5	·94	1	—	
6304·97	6	·99	8	6304	
6293·98	5	4·04	1	—	6266
6276·23	3	—	—	—	
6273·23	3	·26	—	—	
6266·69	6	·66	10	6266	
6258·98	3	9·06	1	—	
6246·90	4	7·00	1	6244	6217
—	—	—	—	6232	
6225·90	3	—	—	—	
6217·44	6	·50	8	6217	
6214·04	5	·13	2	—	
6205·94	5	6·01	1	—	6183
6203·08	1	—	—	—	
—	—	99·34	1	—	
6193·23	3	—	—	—	
6189·24	3	·30	1	—	
6182·28	5	·37	10	6183	Intensity variable
—	—	79·90	1	—	
6175·09	5b	·15	2	6176 vw	
6173·01	1	·02	1	—	
—	—	66·81	1	—	
6163·73	6	·79	10	6163	6144
—	—	57·12	1	—	
6156·36	1	—	—	—	
6150·46	3	·49	1	—	
6143·31	7	·28	10	6144	Not a very accurate value, the line being so near the last
6142·63	2	—	—	—	
6128·63	5	·63	8	6128 vw	
6118·20	4	·22	2	—	
6096·36	6	·37	10	6097	
6074·51	6	·52	10	6075	

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Wave-length.	Intensity.	Baly.	Intensity.	Living and Dewar.	Remarks.
6064·70	3	·36	1	—	—
6046·31	3	·06	1	—	—
—	—	43·20	1	—	} Baly's values for these four lines about 0·3 too low
—	—	32·32	2	—	
6030·20	5	·20	10	6031	Second order. 3013·02
—	—	26·03	1	—	3012·20
—	—	24·40	1	—	„
6001·15	3	·00	1	6001	
5991·80	4	·72	2	5991	
5988·10	4	·00	4	5987 w	
—	—	84·94	1	—	Second order. 2992·47
5982·71	1	—	—	—	
5975·76	5	·78	8	5976	
5974·80	5	·73	6	—	
5966·44	1	—	—	—	
5965·64	3	·50	4	5964 w	
5961·85	2	·64	1	—	
—	—	49·51	1	—	Second order. 2974·76
5945·02	6	·91	10	5945 s	
5939·49	2	·44	1	—	
5934·65	2	—	—	—	
5919·11	4	·08	1	5919 w	
5913·81	4	·82	1	5914 w	
5906·60	5	·54	2	5905 w	
5902·65	5	·57	4	—	
5898·48	1	—	—	—	
5891·68	0	—	—	—	
5882·06	5	·04	8	5882	
5873·02	5	·04	1	—	
5872·27	4	—	—	—	
5868·59	3	—	—	—	
5852·62	10	·65	20	5852·7 vs	
5829·08	2	—	—	—	
5820·29	5	·29	4	5820 s	
5816·76	2	—	—	—	
5811·62	3	—	—	—	
5804·62	5	·57	1	5804 s	
5770·45	0	—	—	—	
5764·55	7	·54	8	5763 s	
—	—	64·20	1	—	
5760·74	4	·72	1	—	
5748·47	5	·44	4	5747	
5719·35	5	·42	1	5718	
5689·96	5	·96	2	5689	
5662·72	4	·76	1	5662 w	
5656·81	4	·80	4	5656	
5656·16	2	—	—	—	
5652·69	2	·67	1	—	
—	—	—	—	5592	
5589·40	1	—	—	—	Not 2794·72
5562·90	4	·96	2	5561	
5538·73	1	—	—	—	
5533·73	1	—	—	5532	
—	—	—	—	5503 vw	
5494·52	1	—	—	—	
5448·64	2	—	—	5447 vw	
5433·78	4	·86	1	5432 w	
5420·29	0	—	—	—	
5418·70	2	—	—	5417 vw	
5412·80	2	—	—	—	
—	—	—	—	5409 vw	
5400·70	6	·77	4	5400	} These lines probably not separable in first order
—	—	00·50	4	—	

Wave-length.	Intensity.	Baly.	Intensity.	Living and Dewar.	Remarks.
5383·35	1				
5375·15	3				
5372·47	4	—	—	5372	
5360·16	4	—	—	5360	
5355·37	3	—	—	5355	
5349·36	1				
5343·40	7	·41	1	} 5341	A pair. L. and D.
5341·24	7	·25	4		
5333·44	0				
—	—	32·33	4		
5330·90	8	—	—	5330	
5326·55	4				
5316·92	1				
5314·93	0				
5304·91	3	—	—	5304 w	
5298·33	4	—	—	5298 w	
5280·25	1				
—	—	78·50	1		
5274·24	0				
—	—	71·50	1		
5234·14	4	—	—	5234	
5222·45	5	—	—	5222	
—	—	18·30	1		
5214·44	1				
5210·68	3	—	—	} 5209	
5208·93	4	—	—		
5203·97	5	·12	1		5204
5193·33	4	—	—	5192	
5191·44	2				
5188·68	5	·79	1	5188	
5158·99	1				
5156·77	0				
5154·54	3				
5152·07	4	—	—	5152	
5150·24	0				
5145·06	5	·15	1	5145	
5122·40	4	—	—	5122	
5120·72	0				
5116·64	6	·72	1	5116	
5113·80	3				
5105·84	1				
5080·52	6	·54	1	5080	
5076·73	0				
5074·35	4	—	—	5074	
5037·87	6	·95	1	5038 s	
5036·12	0				
5031·48	5	—	—	5031	
5023·03	0				
5005·28	2				
4995·02	0				
4957·18	3	—	—	4958 w	
4955·56	0				
4945·05	2				
4939·12	2				
4892·18	2				
4885·05	4	—	—	4884 vw	
4868·35	0	—	—	—	Chromosphere 4068·20, int. 2
4866·60	1				
4865·67	2				
4864·52	0				
4863·22	3				
4852·81	2				

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Wave-length.	Intensity.	Baly.	Intensity.	Liveing and Dewar.	Remarks.
4852·56	0				
4843·01	0				
4837·49	5	·54	1	4838 vw	
4827·52	3				
4823·35	1				
4822·06	3				
4818·94	2	—	—	4819 vw	
4817·80	3				
4811·85	0				
4810·22	3	—	—	4811 vw	
—	—	06·24	1		
4800·29	1				
4790·36	2	—	—	4791 w	
4789·66	0	—	—	—	Chromosphere 4789·70, int. 2
4789·07	4	·07	1		
4780·45	1	—	—	—	„ 4780·39, int. 1
4758·84	1				
4752·91	5	·88	1	4754 w	
4749·74	4	—	—	—	„ 4749·58, int. 1
4725·32	1				
4721·72	1				
4717·77	0				
4715·50	5	·49	4	4715	
4714·59	1				
4713·31	6	·51	2	—	My reading probably the mean of Baly's and He 4713·25
4712·22	3	·23	2		
4710·21	4	·21	2	4710	
4709·00	5	·00	4		
4704·55	5	·56	4	4704	
4702·68	1				
4687·79	1	—	—	4687 w	
4680·50	0	—	—	4680 w	
4679·30	0				
4678·37	1				
4671·09	0				
4667·58	0				
4661·27	2	—	—	? 4664	
4656·57	3	—	—	4657 w	
4650·07	1				
—	—	—	—	4647 w	
4645·59	3				
—	—			4640 w	
4636·82	0	—	—	4636 w	
4636·27	0				
4628·50	2	—	—	4628 w	Hardly visible in fraction 1. Ar. 4628·60
4618·04	0				
4614·55	1	—	—	4616 w	
4610·07	1				
—	—	—	—	4589	
4582·61	2	—	—	4583 w	
4582·18	1				
4575·27	3	—	—	—	Brighter in second fraction
4573·14	1	—	—	—	„ „
4566·04	0				
4540·55	3	·48	1	4540	
4538·49	1				
4537·93	4	·39	1	4538	
4536·40	3				
4534·28	1	—	—	—	First fraction only
4526·04	0	—	—	4526 w	Very faint

Wave-length.	Intensity.	Baly.	Intensity.	Living and Dewar.	Remarks.
—	—	—	—	4523 w	Very faint.
4517·88	0	—	—	4518 w	
4515·04	0	—	—	—	
4510·85	0	·86	1	—	Ar. 4510·90
—	—	—	—	4508 w	Doubtful
—	—	—	—	4500 w	
4591·97	0	—	—	—	Doubtful
4588·23	3	—	—	4488 w	
4483·43	0	—	—	—	
4477·65	0	—	—	—	Doubtful
4475·78	0	—	—	—	
4467·01	1	—	—	—	
4465·79	0	—	—	—	Doubtful
4460·03	0	—	—	4460 vw	
—	—	59·68	1	4457	Ar. 4431·16, int. 2
4433·89	2	—	—	—	
—	—	31·14	1	4431	
—	—	30·33	1	4429	Ar. 4430·35, int. 4
—	—	26·15	2	—	Ar. 4426·16, int. 6
4425·57	2	·57	1	—	L. and D. probably H 4412·35
4424·96	2	·98	2	4424	
4422·70	3	·69	2	4422	
—	—	14·44	1	4413	Very faint. L. and D. give
4395·79	0	—	—	—	4409, 4398, 4392, 4380, 4370 w, and 4365 vw
4363·69	0	—	—	4363 w	Very faint. ? Ar. 4348·11, int. 8
4348·37	0	—	—	4347 vw	
—	—	—	—	—	
4345·33	0	—	—	—	Ar. 4345·27, int. 7
4336·46	0	—	—	—	Very faint. Ar. 4335·42, Chromosphere 4335·49
4335·57	0	—	—	—	
—	—	—	—	—	
4334·31	2	—	—	4334 w	L. and D. 4322 vw, 4315 vw, and 4290 w
4306·48	1	—	—	4306 vw	
—	—	—	—	—	
4275·78	2	—	—	4276	Chromosphere 4275·71
4274·88	1	—	—	—	Chromosphere 4275·71
4270·41	0	—	—	4270 w	
4269·92	1	—	—	—	
4268·18	1	—	—	—	Ar. 4259·50, int. 9
4259·55	1	·53	6	4261 w	
—	—	—	—	—	
4200·84	0	1·03	4	—	L. and D. 4258, 4251, 4241, 4234, 4232, 4220, 4218, and 4206, last being a H line
4198·35	0	·71	4	4198 vw	Ar. 4200·80, int. 10, Chromosphere 4200·73
4191·08	0	·44	2	—	Ar. 4198·40*, int. 10, Chromosphere 4198·73
—	—	90·86	2	—	Ar. 4191·02*, int. 10
4182·10	0	·00	2	—	Ar. 4190·85, int. 7
4175·40	0	—	—	—	Ar. 4182·03, int. 7
4174·60	0	—	—	—	Chromosphere 4174·48
—	—	58·68	4	—	
—	—	—	—	—	
4157·74	0	—	—	—	Ar. 4158·63*, int. 10
4131·06	0	—	—	4131	L. and D. 4151, 4134
—	—	—	—	—	Chromosphere 4130·97
4071·51	0	—	—	—	L. and D. 4128, 12, 4099, 86, 80
—	—	—	—	—	One plate only
—	—	—	—	—	L. and D. 4063, 43, 37, 3985, 80, 33, 05

* Kayser's values are 98·162, 91·841, 58·722, and 67·78 respectively.

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Wave-length.	Intensity.	Baly.	Intensity.	Living and Dewar.	Remarks.
—	—	3899·21	1	3900	Baly's line a ghost
—	—	86·26	1	—	A ghost
—	—	79·49	1	—	L. and D. 3856, 42, 40, 30, 00, 3777, 66
3754·32	3	·31	2	3754	
3733·54	1	—	—	—	L. and D. 3751, 45, 38, 35, 28
3713·27	0	—	—	3713 s	L. and D. 3710
3701·31	5	·30	6	3701	
3694·38	0	—	—	3694 s	
3685·86	4	·84	4	3686	
3682·37	4	·33	4	3683	L. and D. 3664 s, 55, 51
3633·80	5	·78	6	3634	A pair. L. and D. Other constituent of pair He 3634·39
3609·33	3	·27	2	3609 w	L. and D. 3628
—	—	06·61	1	—	Ar. 3606·69, int. 3
3600·32	6	·24	4	3600	
3593·69	8	·67	10	3593 s	
—	—	88·60	1	—	Ar. 3588·64, int. 2
3587·50	0	87·52	1	3587·5 vs	A pair. L. and D.
—	—	·24	1	—	} These lines possibly obscured by halation from 3593
—	—	86·62	1	—	
—	—	67·73	1	—	
—	—	54·39	1	—	
—	—	—	—	—	Ar. 3554·48, int. 5
—	—	—	—	—	L. and D. 3575, 71, 69, 61, 58, 48, 43
—	—	32·30	1	—	
—	—	29·95	1	—	A ghost
—	—	22·92	1	—	"
3520·61	9	·57	8	3521 vs	
3515·32	5	·30	6	3515	
3510·87	4	·87	2	3510 w	L. and D. also give 3504 w
3501·34	5	·34	6	3500	
3498·19	5	·19	6	3498	
—	—	81·94	1	—	A ghost. L. and D. give 3482, 3481
3472·68	6	·70	8	3473 s	
3466·70	5	·72	6	3467	
3464·46	4	·48	6	3464	
3460·61	5	·67	6	3460	
3454·31	5	·30	6	3454	
3450·88	4	·87	4	3451	
3447·83	5	·83	8	3447·7	Not He 3447·73
—	—	38·66	1	—	A ghost
3424·08	3	·05	2	3424	Much brighter in second fraction
3418·03	5	·05	8	3418 s	L. and D. 3417, 07, 04, 3393, 3388
3378·27	0	—	—	3378 s	Doubtful
3375·74	2	·72	1	—	
3370·02	5	·01	6	3370	L. and D. 3374, 72, 67, 63, 62, 60, 58, 45 s, 44, 35 s, 29, 27, 24 s, 19 s, 15, 13, 11, 10, 3297, 54, 50, 44 s, 33, 30, 25, 18 s, 14, 09, 3199
3167·62	2	—	—	3165	
3153·51	2	—	—	—	
3148·70	2	·76	1	—	
3147·82	1	—	—	? 3142	
3126·33	2	·33	1	—	
—	—	92·84	1	—	
—	—	80·05	1	—	

* For footnote, see p. 192.

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Wave-length.	Intensity.	Baly.	Intensity.	Liveing and Dewar.	Remarks.
3079·31	1				
3079·02	1				
3077·08	2	·08	1		
3063·83	2				
3057·51	3	·50	1		
3030·44	2				
3017·47	3				
3013·09	3				
3012·25	3				
2992·57	3				
2982·81	3				
2981·06	1				
2980·81	1				
2979·94	2				
2975·65	1				
2974·89	3				
2949·32	1½				
2947·44	3				
2932·82	2				
2929·47	1				
2913·28	2				
2911·55	1				
2872·74	1				
2862·28	0				
2835·32	1				
2833·04	0				
2825·75	0				
2825·37	0				
2814·77	1				
2796·06	1				
2794·72	0				
2792·39	1				
2775·09	0				
2766·35	0				
2736·19	1				